CHAPTER 2
PARK REACH
FLOOD DAMAGE REDUCTION AND ECOSYSTEM RESTORATION PLAN FORMULATION

DESCRIPTION OF THE PARK REACH

Park Reach Location. The Park Reach is located just north of downtown San Antonio, and just upstream of the San Antonio River Tunnel inlet. Hildebrand Avenue borders the Park Reach on the north, Highway 281 on the west and south, and Broadway Avenue to the east, and is a mixture of residential, commercial, light industrial development, and public facilities. The upper study area contains the San Antonio Zoo west of the river, and the Witte Museum east of the river. Brackenridge Park is located in the central portion of the study area, and contains several landmarks including stone-faced river walls constructed by the Works Progress Administration, Alligator Gardens, Water Works Building and Canal, Confederate Tannery Site, Old Lime Kiln, Joske Pavilion, Acequia Madre Section and the Dionicio Rodriguez Footbridge. The highest concentration of residential development is located near the southern portion of the study area west of the San Antonio River in an area known as the River Road Community. The southernmost portion of the project area contains the Brackenridge Golf Course. Finally, the heaviest concentration of commercial development is located along Broadway Avenue, east of the Catalpa-Pershing Channel. Figure 2-1 is a map of the Park Reach study area.

San Antonio River. The portion of the San Antonio River near the Witte Museum and the San Antonio Zoo has been modified using concreted vertical walls. Within the Brackenridge Park, the banks are natural, though significant bank erosion is occurring in several areas, particularly within the golf course where there is little to no woody riparian vegetation. Some stretches of the river have gentle slopes, creating littoral zones for wading birds, with shallow, slack water areas that support smaller fish and some aquatic and wetland plant establishment. Other areas consisted of undercut banks, which provide shading and refuge for larger fish species. With the exception of the golf course area, portions of the riparian corridor have overhanging woody vegetation providing shade to the water, woody and herbaceous material for the formation of detritus, breeding grounds for terrestrial insects, maturation habitat for aquatic insects, and perch sites for aquatic birds. Sediment islands with naturally established vegetation were observed at several locations. Individual boulders and boulder clusters were evident through much of this reach.

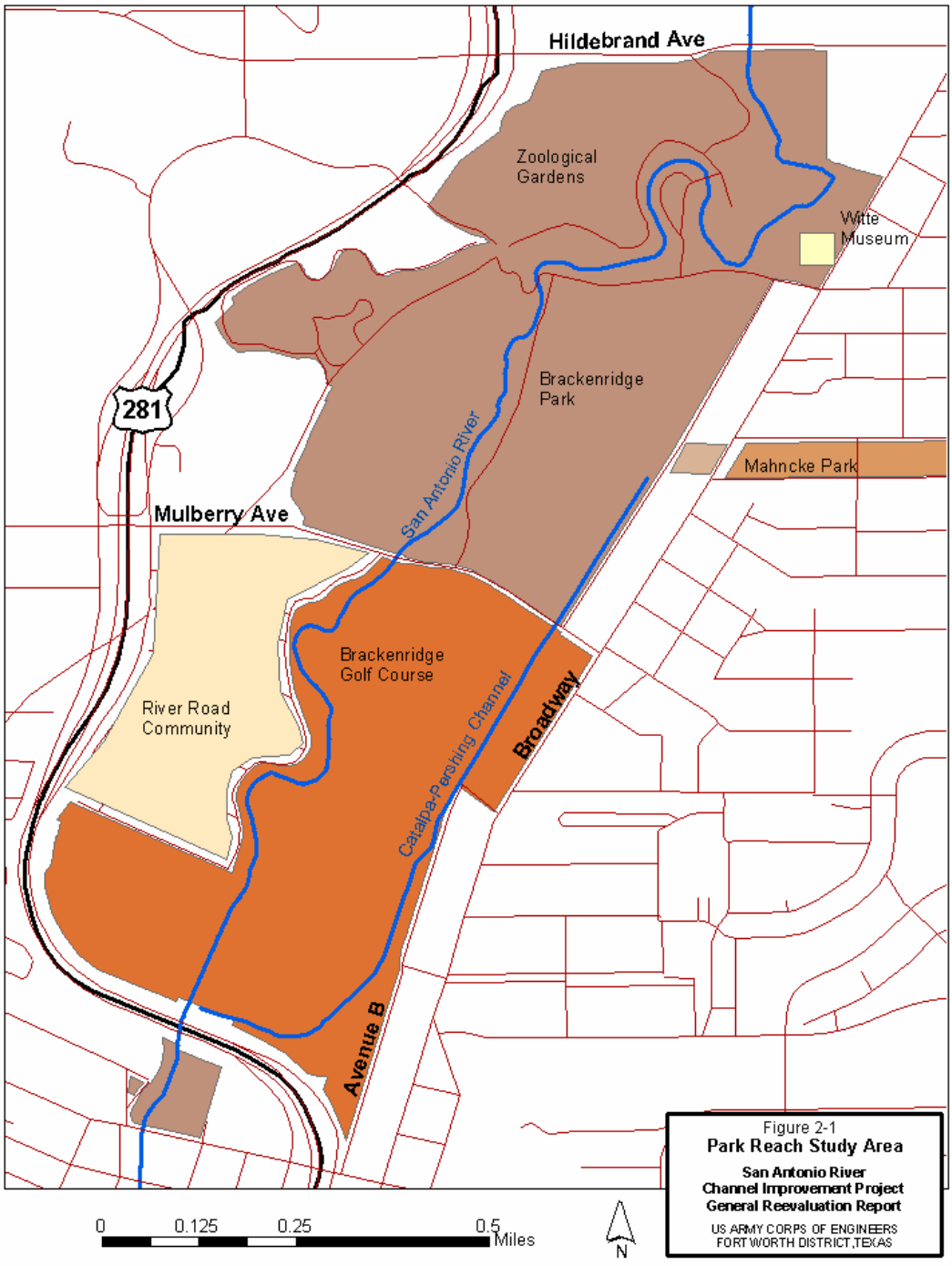
Catalpa-Pershing Channel. The Catalpa Channel was constructed in 1970 for local drainage after the original Catalpa channel was filled as part of the construction of Broadway Avenue. The Catalpa Channel also collects runoff from Fort Sam Houston to the northeast. Storm water runoff enters the channel from an underground culvert running underneath Broadway Avenue just downstream of Parfun Way. A large headwall marks the upstream limit of the channel. The Catalpa-Pershing channel extends from U.S. 281 McAllister Freeway to upstream of Mulberry Avenue (approximately 5300 feet). Approximately 2300 feet of the upstream end of the channel is concrete-lined, with a bottom width of 15 feet, with

3H:1V side slopes. The downstream portion is a natural earthen channel. This channel flows through Brackenridge Park and Golf Course. The channel depth is approximately 15 feet, and the bottom width varies up to approximately 20 feet. The channel parallels the highly developed area along Broadway Boulevard to the east, and joins the San Antonio River upstream of U.S. 281.

Riparian Resources. The riparian habitat consists of a riparian/bottomland hardwood, grass-forbland, maintained grassland savannah, and upland forest. Wildlife living in the study area occupies a modified habitat, influenced by the surrounding urban complex. Wildlife species occurring in the area are those tolerant of human activity such as rabbits, songbirds, squirrels, and small rodents. The riparian habitat along the river ranges from fair to very poor. Some locations are heavily vegetated with exotic species, primarily phragmites and glossy privet. Both species have an invasive nature, out-competing the native vegetation for resources. The privet has formed a thick mid-story canopy effectively shading out all under-story vegetation. Consequently, there is little under- or mid-story vegetation, and no over-story canopy recruitment. There are several areas where the over-story trees are dead or dying and no younger trees exist in the lower levels to take their place.

Most of the areas adjacent to the Catalpa Channel on either side is described as maintained grass-forb parkland or maintained grassland savannah. Johnson grass pervades the banks inside the channel not concrete-lined. Downstream of Mulberry Street, the channel is bordered by the Brackenridge Golf Course on the east, and Lions Field to the west. Within the golf course, the vegetation is a heavily maintained Bermuda grass monoculture with scattered trees including pecan, oak, and elm. Lions Field is characterized by mowed grass-forb parkland.

Wildlife (mammals, birds, and reptiles) observed in the Park Reach during site visits include the fox squirrel (*Scabrous niger),* feral cat (*Felis domesticus),* great egret (*Casmerodius albus),* great blue heron (*Ardea herodias),* little blue heron (*Egretta caerulea),* muscovy duck (*Anser indicus),* wood duck (*Aix sponsa),* mallard (*Anas platyrhynchos),* mourning dove (*Zenaida macroura),* Inca dove (*Columbina inca),* whitewing dove (*Zenaida asiatica),* blue jay (*Cyanocitta cristata),* American crow (*Corvus brachyrhynchos),* tufted titmouse (*Parus bicolor),* Carolina chickadee (*Parus carolinensis),* mockingbird, (*Mimus polyglottos),* white-eyed vireo (*Vireo griseus),* common yellowthroat (*Geothlypis trichas),* yellow-rumped warbler (*Dendroica coronata),* northern cardinal (*Cardinalis cardinalis),* house sparrow (*Passer domesticus),* great tail grackle (*Quiscalus mexicanus),* brown creeper (*Certhia Americana),* American goldfinch (*Carduelis tristis),* slider turtle (Trachemes scripta), and Mediteranian gecko (*Hemidactylus turcicus*).


Hildebrand Ave
Zoological Gardens
Witte Museum
Brackenridge Park
281
San Antonio River
Mahncke Park
Mulberry Ave
Brackenridge Golf Course
River Road Community
Catalpa-Pershing Channel
Broadway
Avenue B
0
0.125
0.25
0.5
Miles
N
Figure 2-1
Park Reach Study Area
San Antonio River
Channel Improvement Project
General Reevaluation Report
US ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT,TEXAS

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Hazardous, Toxic, Radioactive Wastes, and Contaminants. A limited Phase I environmental site assessment was conducted to identify the presence or suspected presence of hazardous, toxic, and radioactive wastes (HTRW) within Park Reach. The assessment consisted of "drive-by" survey, and a historical records review (title search). The Federal records review examined the U.S. Environmental Protection Agency Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Information System, Resource Conservation and Recovery Act (RCRA) and the Emergency Notification System listings. The state records review examined the Texas Commission on Environmental Quality (TCEQ) databases for underground storage tank facilities, leaking underground storage tank facilities, and landfill closures. Records of relevant geological and hydrological information available from the U. S. Department of Agriculture, Soil Conservation Service (now the NRCS), and U. S. Geological Service were also reviewed. This information was obtained to ensure alternatives did not disturb any known or potential site. In the event any recommended plan is likely to disturb any of the identified sites, additional assessments and/or remedial investigations may be required. Table 2-1 displays HTRW generator sites. Appendix H also contains the complete limited phase I environmental site assessment.

Table 2-1
HTRW Generator Sites - Park Reach

Property Number	Site Investigated†	HTRW Generator(s) Within ⅛-mile of Property
82	Brackenridge Golf Course 2315 Ave B, San Antonio, TX 78215	Three registered RCRA "very small/large waste" generators, six registered UST sites, and 10 registered leaking UST sites
109	City of San Antonio	Two registered RCRA "very small/large waste" generators, five registered UST sites, and one registered leaking UST site

Note: UST = underground storage tank. †Address provided if possible.

Cultural Resources. A review of all known historic and prehistoric resources was completed for Park Reach study areas to identify those resources potentially impacted by a recommended plan. Knowing the location of these sites provides the opportunity to avoid or minimize impacts to the sites. Four prehistoric sites, five "collection localities" or artifact scatters, and 17 historic resources were identified within the Park Reach study area. The prehistoric sites and collection localities (CL) previously recorded are identified as sites 41BX264, 41BX293, 41BX323, 41BX1425, and CLs 1-3 and 10-11. Each of these sites consists of a scatter of lithic debris including diagnostic projectile points and other tool fragments in many cases. The historic sites include: the Upper Labor Acequia; the Donkey Barn; the Rodriguez Bridge and Benches; the Reptile Garden; the Alamo Dam and Headgate site and Alamo Madre Acequia (and stone lined channel); the Texas Pioneers, Trail Drivers, and Rangers Memorial Building; the Witte Memorial Museum, the Joske Pavillion; the Iron Tress Bridge; the Water Works Building and Canal; the Lambert Bathing Beach and Changing Rooms; the Confederate Tannery; the Otto Koehler Pavllion; the Second Water Works Building and Canal; and the Garza Mill.

Due to the presence of these 26 resources, and the likelihood that more prehistoric sites exist in areas not previously disturbed, further archaeological surveys, including shovel testing and possibly backhoe testing will likely be necessary. In addition, archaeological monitoring during any ground disturbing construction activities may be required. Appendix I contains the complete archeological background of the study areas.

FLOODING AND FLOOD DAMAGES

The city of San Antonio has experienced recurrent flooding since the early 1900's. Some of the more significant recent flooding occurred in September 1946, October 1998, and June 2002. Besides rainfall, other factors exacerbating flooding and flood damages are increased runoff from urban development and floodplain encroachment. Flooding in the Park Reach comes from two sources; the San Antonio River and the Catalpa Channel. The flooding occurs independently, until approximately the 1-percent annual chance exceedence when the San Antonio River flood plain dominates. Further, the effects of the tunnel inlet just downstream of Highway 281 causes a backwater effect extending upstream to near Millrace Street. The following sections will summarize the methodology, inputs, and results of the analyses conducted to estimate flood damages within the Park Reach.

Methodology and Inputs. The Hydrologic Engineering Center - Flood Damage Assessment program (HEC-FDA version 1.2) is the computer model used to estimate flood damages. The program integrates hydrologic, hydraulic, and structure characteristics to compute single-event and expected annual flood damages. Specifically, the program estimates damages based on the depth of flooding for various (single) flood events and a relationship between the depth of flooding and the finished floor of a structure. Single-event damage estimates were consolidated at specific index points located within each damage reach for input in the HEC-FDA program. Damages to the various structures, accumulated by frequency, produce a frequency-damage function. An integration process using this frequency-damage data calculates estimates of expected annual damages through the application of a Monte Carlo simulation that accounts for uncertainty in the hydrologic, hydraulic and structure characteristics.

Inputs into HEC-FDA include water surface profiles for the 50-, 20-, 10-, 4-, 2-, 1-, 0.4-, and 0.2-percent annual chance exceedance (ACE) flood events (or the 2-, 5-, 10-, 25-, 50- 100-, 250- and 500-year flood, respectively), the type of structure, ground and first floor elevations, structure depreciated replacement value, content value, a flood depth – percent damage relationship for each per structure type, and an uncertainty factor for key parameters. Both the San Antonio River and the Catalpa Channel are divided into reaches to facilitate the analysis of flood damages.

Value of Flood Plain Investment. A total of 162 structures are located in the Park Reach within the 0.2-percent ACE flood plain having an estimated value of $50.8 million. Including privately owned vehicles, the flood plain investment totals $52.6 million. Of the 162 total structures, 65 are attributed to the San Antonio River having an estimated value of $31.3 million (including vehicles), and 97 are attributed to the Catalpa Channel having an

estimated value of $21.3 million. Table 2-2 displays a summary of the flood plain investment. Note the number of structures within the 4-, 0.4-, and 0.2-percent ACE flood plains is omitted from the table.

Single Event and Expected Annual Damages. Single event damages were estimated on four separate subreaches along the San Antonio River. The four subreaches include the River Road neighborhood, the Brackenridge Golf Course, San Antonio Zoo and Zoological Gardens, and the Witte Museum. There are two subreaches for the Catalpa Chanel, the Upper and Lower. Flood damages are primarily to structures and their contents. A relatively small amount of damages to privately owned vehicles, as well as National Flood Insurance Program costs has been estimated, and are included in the average annual damages. Damages are summarized below for each subreach. Table 2-3 displays a summary of single event damages.

San Antonio River - River Road. The River Road subreach contains exclusively single-family, residential structures. There are 20 structures within the 0.2-percent ACE having an investment value of about $4.7 million (structure and contents). Flood damages begin prior to the 50-percent ACE to a single structure. The 1-percent ACE affects 17 structures, causing $17,000 in flood damages. Expected annual damages are estimated at $23,000.

San Antonio River - Brackenridge Golf Course. The Brackenridge Golf Course subreach contains structures and facilities solely with the golf course. There are four structures within the 0.2-percent ACE, the total investment value is estimated at $4.0 million. The structures include the clubhouse, banquet, and maintenance structures. In addition to structure and content damages, damages are estimated the golf course itself. Damages are expected to begin prior to the 50-percent ACE. The 1-percent ACE causes $180,000 in damages. Expected annual damages are $79,000.

San Antonio River - San Antonio Zoo. The San Antonio Zoo subreach contains those structures ands facilities associated with the zoo including exhibits, concessions, and maintenance facilities. There are two, single-family, residential structures within this subreach. There are a total of 7 structures, and an investment value of about $1.6 million including zoo animals. Damages begin prior to the 10-percent ACE, the estimated 10-percent ACE damages are $71,000. The 1-percent ACE causes $182,000 in damages. Expected annual damages are $33,000.

San Antonio River - Witte Museum. This subreach includes the main Witte Museum and 3 ancillary buildings, and Pioneer Hall located west of the San Antonio River, and a number of single-family residential and commercial structures east of the San Antonio River and Broadway Avenue. Total flood plain investment within the 0.2-percent ACE is $20.9 million. Significant flood damages begin prior to the 50-percent ACE, primarily to the Witte Museum ancillary buildings (these are pioneer structures, that have been relocated to the current site), and are culturally significant. The 50-percent ACE causes $198,000 in flood damages, and the 1-percent ACE causes $2.4 million in damages. Expected annual damages are $264,000.

Catalpa Channel-Upper. This subreach contains a mixture of single-and multi-family residential, and commercial structures east of the channel along Broadway Avenue. A total of 74 structures lie within the 0.2% ACE having an investment value of $14.6 million. Flood damages begin to accrue prior to the 2-percent ACE. The 1-percent ACE affects 65 structures, and causes $2.5 million in damages. Expected annual damages are $149,000

Catalpa Channel-Lower. This subreach contains a mixture of single- and multi-family residential, and commercial structures east of the channel along Broadway Avenue. A total of 23 structures lie within the 0.2% ACE having an investment value of $5.0 million. Flood damages begin to accrue prior to the 4-percent ACE. The 1-percent ACE affects 14 structures, and causes $241,000 million in damages. Expected annual damages are $11,000.

Future Without-Project Condition. Under the future without-project condition, flood damages and costs will continue. Future increases in flood damages resulting from additional development within the watershed, manifesting itself either as an increase in precipitation run-off and increased flood depths, and/or an increase in the number of damageable property, are not anticipated or accounted for in this analysis of flood damages.

Discussion, Summary and Conclusions on Without Project Flood Damages. The analysis of without project flood damages has demonstrated significant flood damages, both in terms of frequency, single-event, and annual damages. There is the potential for alternatives to reduce flood damages, particularly within the Witte Museum subreach of the San Antonio River and the Upper subreach of the Catalpa Channel. While alternatives developed to reduce flood damages in these areas may also have the effect of reducing flood damages in the remaining subreaches, given the frequency, magnitude, and spatial distribution of damages, alternatives will not be formulated specifically for these subreaches.

Table 2-2
Number of Structures per Flood Plain
And
Flood Plain Investment (Structures and Contents)

	Number of Structures per Flood Plain					Investment Value ($000)		
	50%	20%	10%	2%	1%	Structures	Contents	Total
San Antonio River:								
River Road	1	4	5	11	17	3,170	1,585	4,755
Golf Course	2	2	2	4	4	4,029	0	4,029
Botanical Garden	0	0	5	6	6	797	761	1,558
Witte Museum	7	10	12	20	28	13,034	7,875	20,909
Total San Antonio River	10	16	24	41	55	21,030	10,221	31,252
Catalpa Channel:								
Upper	0	0	0	62	65	9,840	4,748	14,588
Lower	0	0	0	8	14	3,275	1,722	4,997
Total Catalpa Channel	0	0	0	70	79	13,115	6,470	19,586
Total Park Reach	10	16	24	111	134	34,145	16,692	50,837

Table 2-3
Single Event Damages and Expected Annual Damages
Structures and Contents
($000; February 2004 Price Level; 5 5/8-Percent)

	Single Event Damages					Expected
	50%	20%	10%	2%	1%	Annual Damages
San Antonio River:						
River Road	3	27	59	157	205	23
Golf Course	39	77	96	137	180	79
Botanical Garden	0	0	71	144	187	33
Witte Museum	156	203	244	1,566	2,384	264
Total San Antonio River	198	307	470	2,004	2,956	399
Catalpa Channel:						
Upper	0	0	0	2,491	3,179	149
Lower	0	0	0	64	252	11
Total Catalpa Channel	0	0	0	2,555	3,422	160
Total Park Reach	198	307	470	4,559	6,378	598

Flood Damage Reduction Measures. There are two types of measures used to reduce flood damages. Nonstructural measures attempt to avoid flood damages by modifying or removing properties from the flood prone areas. These measures do not affect the frequency or level of flooding within the floodplain; rather, they affect floodplain activities. Structural flood damage reduction measures consist of means designed to control, divert, or exclude the flow of water from the flood prone areas. Structural measures include detention, diversion, levees and floodwalls, and hydraulic channel modifications.

Within the Park Reach, a segment of the authorized SACIP was never constructed. This portion is known within the Fort Worth District as Unit 8-5-2. This portion of the authorized project consisted of a diversion of the San Antonio River beginning near Hildebrandt Street and using the same alignment as the existing Catalpa Channel and reentering the river near U.S. 281.

Floodplain Management. Floodplain management is most effective in controlling future development of the floodplain, thereby assuring that the existing flood problems do not become worse. However, floodplain management cannot, by itself, significantly alleviate existing flooding conditions within an existing floodplain. The technique of controlled land use is particularly helpful in planning for future development but is of limited use in highly developed areas. Effective regulation of the floodplain is dependent on developing enforceable ordinances to insure that floodplain uses are compatible with the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building codes.

San Antonio currently participates in the National Flood Insurance Program (NFIP). Since joining this program, San Antonio has enacted and enforced numerous floodplain landuse restrictions, regulations, zoning ordinances, subdivision regulations, and building codes. While these measures will not reduce flood damages to the majority of the existing structures in the study area, they are important management tools. Regardless, this does not warrant further evaluation due to its inability to address existing damages. It should be noted that San Antonio will be required to complete and execute a floodplain management plan within one year of the completion of any flood damage reduction plan implemented by the Corps of Engineers.

Flood Forecast and Warning. Flood forecast and warning involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in evacuation of persons and some personal property. Notification of impending flooding can be by radio, siren, individual notification, or by more elaborate means such as remote sensors to detect water levels and automatically warn residents. These measures normally serve to reduce the hazards to life and damage to portable personal property. Flood warning and emergency evacuation should be considered as part of any flood control plan. Since the City of San Antonio already has a flood warning system in place, it will not be considered further in this study.

Flood Proofing. Flood proofing of structures can include providing water tight coverings for door and window openings, raising structures in place, raising access roads and

escape routes, constructing levees and floodwalls around individual buildings or groups of buildings, and waterproofing walls of structures. Flood proofing is more easily applied to new construction and more applicable where flooding is of short duration, low velocity, infrequent, and of shallow depths, and is also appropriate in locations where structural flood protection is not feasible or where collective action is not possible. Flood proofing techniques would require major modifications to existing structures. For water levels that are lower than the first floor of a home, flood proofing would certainly be a possibility. However, if a sustained water level in excess of one foot of the first floor elevation, the structural stability of a watertight home becomes a critical factor. A flood proofed structure generally cannot withstand hydrostatic pressures when water rise three feet above the lowest floor. In addition, flood proofing introduces uncertainties in the degree of protection, since the owner must be present (or awake) to close off windows, doorways, etc. Additional shortcomings include not being able to protect public facilities such as roads, bridges, and utilities, and the continued threat of road closures causing isolation of residents trapped in their homes and businesses. While flood proofing would not likely result in any significant or permanent adverse impacts to ecological or cultural resources, and is appropriate under certain conditions, it does not address the planning objectives or criteria previously discussed. Therefore, flood proofing will not be considered further.

Floodplain Evacuation. Floodplain evacuation (or buyout) as it is commonly known, involves the acquisition, demolition, and removal of structures from the floodplain, and the relocation of residents to flood-free housing. The practicality of evacuation depends on several factors. They include the frequency and severity of flooding, the willingness of residents to move out of the floodplain, the availability of flood-free housing, the value of the property, and the need for areas of a more compatible floodplain use such as parks or nature areas. Permanent evacuation is a very effective means of reducing flood damages, as well as public damages and costs.

Past investigations have demonstrated that permanent evacuation is typically cost effective only up to and including the 10% ACE (10 year) floodplain. Within the study area, there are a total of 25 structures within the 10% ACE floodplain. Based on this assessment alone, structures within the 10% ACE floodplain are overwhelmingly public, commercial, and recreational and are not likely to relocate, or would be extremely expensive to relocate. Regardless, flood plain evacuation will be considered further in this study for residential structures.

Detention. This measure consists of constructing one or more structures to provide flood storage to detain peak flood flows and lessen downstream flood damages. Detention is used to temporarily impound floodwaters for later release when the downstream conditions permit. The feasibility of this measure depends heavily on the volume and timing of the flood flows, and the availability of an impoundment site capable of providing sufficient storage. However, given the lack of a suitable detention site, detention will not be considered further in this study.

Diversion. Diversion of excessive flow into subsidiary channels can be an effective means of reducing peak flows and thereby reducing shear stress on any one system. The

initial plan as part of the authorized project identified a diversion channel on the San Antonio River beginning near the Witte Museum and reconnecting to the San Antonio River near what is now the Highway 281 just upstream of the tunnel inlet. Preliminary analyses indicate the diversion of the San Antonio River into the Catalpa Channel warrants further investigation.

Levees and Floodwalls. Levee systems traditionally provide high levels of protection to flood prone areas but often require substantial amounts of real estate between the stream and the structures being protected. Floodwalls (usually made of concrete) are used in lieu of levees in situations where the acquisition of real estate for a levee, or other topographic problems, may be prohibitive. The feasibility of either of these measures is based on the cost and availability of real estate, the number of structures along the levee alignment, and the additional costs necessary to alleviate interior drainage problems to prevent induced damages in adjacent areas. Construction of individual levees or floodwalls around specific structures or small groups of structures is normally considered cost prohibitive unless the individual structure is very valuable, has cultural significance, or is prone to frequent flooding.

The proximity of structures and the potential lack of available space make levees less feasible because of the anticipated high relocation cost associated with removal of structures where the levees would be constructed. Floodwalls, which require less real estate acquisition, are historically much more expensive than other measures, either structural or nonstructural. It was decided that levees and or floodwalls did not warrant further consideration given the spatial distribution of damageable property and the anticipated relatively high cost

Hydraulic Channel Modifications and/or Bridge Modifications. This measure consists of modifying an existing channel by either increasing the cross-sectional area of the stream channel and/or an existing bridge (widening and/or deepening), straightening and realigning the stream channel, and/or reducing the friction losses of an existing channel through concrete lining. The design of the channel modification can vary significantly and is primarily based on the topography of the existing stream channel and the existing development of properties within the floodplain. Other factors to consider in the design of these hydraulic channel improvement alternatives include the existence of known or potential significant biological/ecological resources, cultural resources, or HTRW. Preliminary investigations indicate that modifications to the bridges spanning the Catalpa Channel as well as modifications to the Catalpa Channel warrants further study.

Analysis of Flood Damage Reduction Measures

Permanent Evacuation. An evaluation of a permanent evacuation of the 50-, 20- and 10-percent annual chance exceedence flood plain was undertaken along both the San Antonio River and the Catalpa Channel. There are 2, 6, and 7 total residential structures for the respective flood plains along the San Antonio River. There are no residential structures within the 10-percent ACE along the Catalpa Channel. Commercial structures along Broadway Avenue and the Witte Museum were not considered for permanent evacuation. Expected annual flood damages prevented from a permanent evacuation are $12,400, $15,400, and $18,600, respectively. This magnitude of flood damage reduction is not

sufficient to economically justify a permanent evacuation alternative. Annual project costs (using a 50-year project life at the current Federal interest rate of 5-5/8-percent) would require the total estimated first cost per structure not exceed $103,400 per structure for structures within the 50-percent ACE, and $44,000 per structure for structures within the 20- and 10% ACE. Given the expected cost to acquire the property (structure and land), final design, plans and specifications including analysis of hazardous material removal and disposal, supervision, and administration, first and annual costs will certainly exceed the thresholds for economic feasibility. Given the lack of economic feasibility, permanent evacuation was not considered further as a means to reduce flood damages.

Diversion and Channel Improvements. Between 1995 and 1997, a preliminary assessment on a number of alternatives for reducing flood damages was completed. The first alternative began with a diversion of the San Antonio River into the Catalpa Channel. The diversion would be begin with a 90-foot long gabion channel with a 40-foot bottom width and 3H:1V side slopes and transition into three, 10-foot by 10-foot concrete box culverts. The culverts would run underground, and transition into the existing Catalpa Channel. From this point, the Catalpa Channel would be widened on the west side to provide a 35-foot bottom width with 1.5H:1V side slopes. The existing Mulberry Street Bridge would be replaced with four, 10- by 10-foot concrete box culverts. Downstream of the Mulberry Street Bridge, the Catalpa Channel would again be widened on the west side providing a bottom width varying between 30- and 40-feet. To the Millrace Street Bridge. The Millrace Street Bridge would be replaced with four, 10- by 10-foot box culverts. Downstream of the Millrace Street Bridge, the existing natural channel would be replaced with a concrete lined channel with a riprap transition at the downstream terminus. The second component of this alternative involves increasing the flow capacity of an existing diversion of the San Antonio River. This diversion begin just downstream of Hildebrand Avenue and connects back into the river at the existing Water Works Building Bridge. The original bridge archways were altered by inserting two, 48-inch concrete pipes and plugging the remaining opening. Removing the plug and concrete pipes will increase the capacity of the diversion. Together, this alternative was estimated to have a total project cost of $5,570,000 (April 1997 price levels). Average annual costs and benefits were estimated at $478,000 (not including land and environmental mitigation costs) and $124,500, respectively, and a benefit-cost ratio (BCR) of 0.3. This alternative was not economically justified.

The removal of the plug and the concrete pipes on the Water Works Building Bridge diversion was considered as a stand-alone alternative. It has an estimated annual cost and benefit of $10,300 and $26,400, respectively, and a BCR of 2.6. Although economically justified, this alternative does not provide any meaningful flood damage reduction, and presents concerns over the impact to significant cultural resources. It was not considered further.

The final alternative investigated is similar to the first alternative except the diversion channel from the San Antonio River to the Catalpa Channel would be located on the surface, as opposed to underground. This grass-lined trapezoidal channel would have a 30-foot bottom width, 3H:1V side slopes, and an average depth of 10-feet. This alternative has an

estimated annual cost (not including lands and environmental mitigation) and benefit of $100,900 and $122,600, respectively, and a BCR of 1.2.

The current plan formulation took into account the findings and conclusions of the above analysis. It was clear that a modification to the Water Works Building Bridge, and an underground diversion from the San Antonio River to the Catalpa Channel was not feasible, and therefore not considered further.

The first iteration evaluated the impact of replacing the existing Millrace and Mulberry Street bridges to reduce flood damages along the Catalpa Channel by removing the constriction caused by the existing box culverts. The Millrace Street Bridge would be replaced with three 50-foot spans with abutments and approach slabs. Also included would be a 50-foot channel transition into the bridge and a 100-foot transition out of the bridge. The Mulberry Street Bridge would be replaced with a single, 80-foot span with abutments and approach slabs. Also included would be a 50-foot channel transition into and out of the bridge. Replacing the two bridges resulted in a reduction of nearly all (99.5-percent) flood damages along the Catalpa Channel. Expected annual benefits and costs are $159,000 and $145,000, respectively, for a benefit-cost ration of 1.08. The bridge modifications had no impact on flooding along the San Antonio River.

Turning next to the San Antonio River, hydraulic channel improvements and a diversion of the San Antonio River to the Catalpa Channel are considered. Hydraulic channel improvements to the San Antonio River were initially discounted because of the destruction of the only remaining riparian corridor along the San Antonio River upstream of the tunnel inlet. This led to the evaluation of a diversion channel. The location of the diversion channel sought to reduce flood damages for the River Road community, San Antonio Zoo, Witte Museum, and the northern portion of Broadway Avenue, and took into account the magnitude of damages of each damage center, the length of the diversion, impacts to environmental and cultural resources, and other impacts. Further, it was believed the Catalpa Channel with the bridge replacements has the capability to convey significantly additional flow. The diversion would begin about 550-feet west of Avenue B, immediately north of Tuleta Street. A weir would divert flows into the channel starting with the 20-percent annual chance exceedence. The channel would traverse south along the west side of Avenue B. The diversion channel is approximately 1,700-feet in length, has a 30-foot bottom width and side slopes of 3 horizontal on 1 vertical (3H:1V), and will transition into the Catalpa Channel at the headwall. The diversion channel will require the construction of a bridge at Tuleta and Parfun Way, as well as two railroad bridges for the Eagle railroad. Although the diversion channel will pass through the existing city nursery, the nursery is being relocated and the existing buildings removed. This action is not the result of the development of these alternatives or any potential recommended plan. No utility relocations are identified at this time. The diversion channel reduced flood damages by 31-percent along the San Antonio River, and had average annual benefits and costs of $125,000 and $284,000 respectively. With a benefit-cost ratio of 0.44, this alternative was not economically feasible.

A larger diversion channel was evaluated next. This diversion channel also includes the weir structure but differs in that a concrete pilot channel will start at the diversion structure.

The pilot channel has a length of 128-feet with a 3-foot bottom width and 2-foot vertical walls, and transitions into the diversion channel. The diversion channel has a length of about 1,625 feet with a channel width starting and 86-feet and widening to 148-feet at the transition into the Catalpa headwall. Side slopes will be 3H:1V on the east bank, and vertical concrete on the west bank. This diversion channel would also require anew bridge at Tuleta and Parfun Way, as well as the railroad bridges. This diversion channel reduces flood damages by 45-percent along the San Antonio River, and has average annual benefits and costs of $179,400 and $479,000, respectively. With a benefit-cost ratio of 0.37, this alternative also was not economically feasible.

In an attempt to reduce flood damages even more along the San Antonio River, particularly for the Witte Museum, another diversion channel alternative was evaluated. A diversion structure would be located upstream of the Witte Museum on the east bank of the San Antonio River. The diversion channel would traverse east of the Witte Museum, cross Tuleta Street, and eventually meet the alignment of the first diversion channel investigated. The total length of this diversion is about 2,800-feet, and would have a bottom width of 30-feet and 3H:1V side slopes. The diversion channel would require storm sewer modifications, new bridges at Tuleta and Parfun Way, and new railroad bridges. This diversion channel reduced flood damages by 73-percent along the San Antonio River, and had average annual benefits and costs of $290,400 and $574,000 respectively. With a benefit-cost ratio of 0.51, this alternative also was not economically feasible.

Although modifications to the San Antonio River were initially removed from consideration early in the study due to the destruction of the riparian corridor, it was discovered that modifications may be made to the upper reaches on the west bank of the river across from the Witte Museum without destroying any riparian corridor. A portion of the overbank could be removed providing addition conveyance without disturbing the river bottom or bank. This alternative reduced flood damages by 38-percent along the San Antonio River, and had average annual benefits and costs of $152,200 and $165,000, respectively. With a benefit-cost ratio of 0.92, this alternative was not economically feasible.

The initial (smaller) diversion channel was evaluated along with the San Antonio River modification. This alternative yielded a greater decrease in flood damages (higher flood damage reduction benefits). This alternative reduced flood damages by 77-percent along the San Antonio River, and had average annual benefits and costs of $305,800 and $459,000, respectively. A benefit-cost ratio of 0.67 makes this alternative economically unfeasible.

Table 2-4 displays a summary of first costs, annual costs, annual benefits, and benefit cost ratios for the alternatives evaluated.

Table 2-4
Benefit-Cost Summary
($000 (rounded); February 2004 Price Level; 5 5/8-Percent)

	Catalpa-Bridge Replacement	San Antonio River – Small Diversion	San Antonio River – Larger Diversion	San Antonio River – Witte Diversion	San Antonio River-Modification	San Antonio River-Modification & Small Diversion
Without-Project Damages	160	399	399	399	399	399
With-Project Damages	1	274	219	108	247	93
Percent Damages Reduced	99	31	45	73	38	77
Annual Benefits	159	125	179	290	152	306
Total First Cost	2,404	4,591	7,831	9,241	2,616	7,430
Annual Cost	144	284	479	574	165	459
Benefit-Cost Ratio	1.08	0.44	0.37	0.51	0.92	0.67

Discussion, Summary, and Conclusions. No alternatives investigated were found to be economically feasible except the bridge replacements on Catalpa Channel. According to Corps of Engineers policy, the Corps does not participate in the replacement or modification of bridges as a stand-alone flood damage reduction measure. The replacement or modification of bridges is a non-Federal responsibility. Therefore, the Corps cannot recommend an alternative for implementation on the Catalpa Channel.

The modification to the San Antonio River appears to be the most likely alternative. However, even though it is close to being economically feasible, it is not reasonable to expect further detailed analyses to change this result. Further, this alternative only reduces flood damages by 38-percent. More importantly, significant flood damages continue to accrue at very frequent flood events. This alternative does not appear to be either a complete or efficient means of reducing flood damages.

A major factor in the high costs for the alternatives is land costs. The diversion channel from the San Antonio River to the Catalpa Channel cuts through Brackenridge Park. Lands costs are estimated at $3.44 per square foot, or approximately $149,800 per acre. The cost of the land required for the project is prohibitive. Further, additional land is required for environmental mitigation. Coordination with the U. S. Fish and Wildlife Service on alternative environmental impacts identified three potential mitigation plans. They are replacing the disturbed area with an equal amount of vegetation either within another

location within Brackenridge Park or the Brackenridge Golf Course along the natural portion of the Catalpa Channel, or restoring an old river remnant within the golf course. Although moot at this point, none of the alternatives investigated were expected to impact any known or potential significant cultural or archeological resources, or disturbed any known or potential hazardous, toxic, radioactive wastes or contaminants.

In conclusion, the Corps of Engineers has no Federal interest in implementing a flood damage reduction project within the Park Reach. The last remaining portion of the authorized project will remain uncompleted.

ECOSYSTEM RESTORATION

Construction of public facilities (zoo, museum, golf course, etc.) and general urbanization of the surrounding area are responsible for ecosystem degradation of this reach. Aquatic habitats have been impacted by removal of vegetation, and increased water velocities from stormwater runoff. Riparian habitats have been impacted by clearing of large tracts of land, resulting in fewer natural resources for both aquatic and terrestrial communities. This perturbation of the natural system has allowed many invasive species to become established within the area. During a site reconnaissance, the primary problems noted were the presence of exotic species, degradation of the riparian corridor, lack of flood plain pools, and bank erosion.

An evaluation of the existing ecosystem condition was undertaken. The results from the evaluation of the without- (existing and future) project aquatic and riparian habitats are presented below for the Park Reach. A detailed description of the processes and analyses used in included in Chapter 3 – Mission Reach Plan Formulation.

Aquatic Habitat Evaluation. Delineation of habitats for the Catalpa-Pershing channel was not necessary because the channel is dry during baseflow conditions; therefore, the channel provides no aquatic habitat for existing conditions.

Delineation of channel features (pools, chutes, and chutes below pool) along the San Antonio River was accomplished using output from the HEC-RAS existing condition hydraulic model run at a 20 cfs baseflow condition. Outputs provided for each river station from the model included: velocity, depth, water surface elevation, cumulative surface acres, and water flow width. These data were placed in a table, and the different channel features, or habitats, listed above were delineated using the table outputs. The vegetated channel was delineated based upon field observations by U.S. Army Corps of Engineers, Engineering and Research Design Center (ERDC) and aerial photos. Overhanging vegetation (vegetation cover) was estimated from field observation and aerial photos. Substrate information was added to the spreadsheet by ERDC base upon their field data. Once delineated, the spreadsheet was sent to ERDC to establish the HSI for each parameter. Table 2-5 displays the surface area (acres), average HSI, and total HUs for each habitat category for the existing and future without project conditions.

Table 2-5
Without Project Aquatic Habitat Suitability Index and Habitat Units

	Existing			*Future Without*					
Habitat Category	**Acres**	**HSI Range**	**HU**	**Acres**	**Year01 HU**	**Year05 HU**	**Year15 HU**	**Year25 HU**	**Year50 HU**
Old River Bendway (0)	0.0	0.00	0.0						
Chute (2)	1.31	0.5-0.78	0.13						
Chute Below Pool (1)	0.43	0.19	0.03						
Embayment (0)	0.0	0.00	0.0						
Vegetated Channel (1)	3.48	0.2	0.61			No Change			
Pool (3)	7.31	0.1-0.7	1.08						
Riffle (0)	0.0	0.00	0.0						
Scour Pool (0)	0.0	0.00	0.0						
Catalpa-Pershing	5.42	0.00	0.0						
TOTAL	**17.95**		**1.85**						

The San Antonio River within the Park Reach is dominated by pool (58%), vegetated channel (27%), chute (10%), and chute below pool (3%) habitats. Habitat quality was reflected in low HSI (< 0.55) in most individual habitat features due to large substrates in upper segments and sub-optimal vegetative growth in the lower segments. Habitat quality of the lowermost chute and pool was relatively high (HSI ~ 0.80). Habitat Units for all habitat categories are substantially lower than habitat area, indicating low suitability of sites within a category or for large areas of water within a category.

The Park Reach results show 5.44 HUs of output for 17.95 acres of aquatic habitat (only 30 percent of acreage provides habitat). The outputs for both the San Antonio River and Catalpa-Pershing Channel demonstrate an opportunity to greatly improve the aquatic habitat with the implementation of ecosystem restoration measures that specifically address the needs of the aquatic habitat.

The baseline analysis indicates that changes in water velocity are not required for substantial gains in habitat value. Suitability is limited principally by the low availability of smaller substrates (fines, sand, and fine gravel) and riparian vegetation, and to a lower degree, deeper water (> 40 cm). Substantial gains in extant habitats can be realized by removing large, unnatural substrates, re-vegetating shorelines, and by creating (or connecting) off-channel habitats (embayments, tributary mouths, old channel bendways).

While technically considered an aquatic resource, the Catalpa-Pershing Channel was determined to have no aquatic habitat value (HU = 0.0). Primary problems observed for the channel were the lack of a dependable stream flow, lack of natural streambed and banks due to concrete lining, lack of riparian vegetation, lack of features which create slack water areas, lack of floodplain pools, and the presence of non-native vegetation species, which are especially problematic in the wetland area.

Riparian Habitat Evaluation. Table 2-6 displays the habitat suitability index (HSI), surface area (acres) and habitat unit (HUs) for the various cover types (habitats) within the Park

Reach at year 1-, 5-, 15-, 25-, and 50 of the study (existing and future without project), as determined by the USFWS.

Table 2-6
Without Project Riparian Habitat Suitability Index and Habitat Units

		Existing		Future without project				
Habitat Category	Acres	Avg. HSI	HU	Year 1 HU	Year 5 HU	Year 15 HU	Year 25 HU	Year 50 HU
Grassland	41.49	0.43	14.4	14.4	14.4	14.4	14.4	14.4
Woodland	196.46	0.30	53.4	53.6	54.5	56.7	58.9	64.4
Total	**237.95**		**67.8**	**68.0**	**68.9**	**71.1**	**73.3**	**78.8**

The mean composite suitability index was based on the raccoon, barred owl, fox squirrel, and shelterbelt models. The mean HSI score for all Park Reach sites was low (HSI 0.30).

Barred owl habitat is very low (HSI 0.03) due to a lack of large overstory trees. Fox squirrel habitat scored low (SI 0.20) due to the lack of large overstory trees. Raccoon habitat was generally low (HSI 0.36) due to a lack of refuge sites (e.g., large fallen trees). The Park Reach currently provides 53.44 Habitat Units (acres). Note that the HUs within the Park Reach are projected to slightly increase by the USFWS, due primarily to maturation of trees. However, the ratio of HUs to total acreage is small indicating that the overall suitability of riparian habitat within the Park Reach will remain low.

The grasslands of Brackenridge Park are biologically limiting, since they mostly occur in the golf course. The HUs for grassland habitat within the Park Reach are projected by the USFWS to remain exactly the same over the next 50 years, with habitat suitability completely lacking for wildlife.

Future Without Project Condition. The future without project condition is expected to remain the same for aquatic habitats. With no improvement to the aquatic habitat, there would be no opportunity for native species to recover within the system, and the percent of non-native and tolerant species may increase. No additional habitat would be provided by the Catalpa-Pershing Channel. With the continued maintenance practices, maturation of trees in the existing woodland patches, and continued expansion of invasive species within the riparian corridor, habitat values are expected to slightly decrease, stay the same, or slightly increase depending on the local circumstances. The net result for the Park Reach would be a slight increase in the overall HUs over a 50-year period, however, the overall suitability as wildlife habitat would remain very low.

Specific Ecosystem Problems and Opportunities. Urban development within the Park Reach portion of the study area have adversely impacted the fish and riparian habitat within and adjacent to the San Antonio River. The degradation is defined by the physical characteristics, lack of diversity, sustainability, and variation in physical structure in both the aquatic and riparian communities, illustrated by the following:

- Altered hydrologic regime causing the loss of natural river and flood plain structures, and consequently -
  - A lack of food, shelter, and breeding habitat for fish species
  - Lack of food, shelter, and nesting habitat for resident and migratory waterfowl and wading bird species.
- The destruction of native riparian vegetation, and as a result:
  - A lack of vegetation at waters edge.
  - A lack of vegetative cover over the water
  - A lack of food, shelter, and nesting habitat for riparian bird species.
  - A lack of food, shelter, and breeding habitat for riparian wildlife.
  - A proliferation on non-native, invasive vegetation
  - Diminished connectivity between upland and riparian habitats
  - Diminished connectivity between upland and aquatic habitats
  - Diminished connectivity between riparian and aquatic habitats

Ecosystem Restoration Measures. Based on the analyses utilized to define the without project condition (existing and future) and identify the level of ecosystem degradation, the prospect of restoring ecosystem functions and values have been identified in the Park Reach. Various measures have been identified to address the previously discussed planning goals and objectives. These measures include, but are not limited to:

Restore Catalpa Channel. Restoring the aquatic habitat within the channel will require a permanent source of water. The initial formulation identified the water available from the diversion of the San Antonio River into the Catalpa Channel (for flood damage reduction) as a good source of this water. However, given this flood damage reduction component is not feasible, another source of permanent water was required. Three options were considered. The first was simply to divert water from the San Antonio River into the Catalpa Channel. However, this method was not regarded as viable given it would require the removal of a large number of mature trees. Second a pipeline was considered either pumping water from the San Antonio River or using available reuse water. Again, after careful deliberation, an "artificial" source of water was not recognized as true restoration. No other sources of restoring a permanent, natural flow to the Catalpa channel were identified. Without this water, the restoration of the Catalpa Channel, including the following features cannot be accomplished. They included:

- Removing the concrete sidewalls and concrete bottom to allow restoration of terrestrial and aquatic habitats creating a sediment, gravel or cobble, permeable channel bottom to provide substrate diversity.
- Re-sloping banks to provide suitable conditions for revegetation.
- Restoring pool, riffle, run complex which vary water depths and velocities.
- Restoring floodplain pools.
- Creating embayments to provide slackwater habitat
- Revegetating channel banks (riparian corridor) with native grass/forbs and woody vegetation to increase food, shelter, and nesting habitats, and to increase vegetation along edge of water.

- Add boulders where feasible to improve aquatic habitat structure and diversity.

San Antonio River Restoration Measures. To restore the existing riparian corridor along the San Antonio River to a less degraded condition the following measures will be considered: (1) To improve the food, shelter, and nesting habitat for terrestrial wildlife, emphasis will be placed on diversifying the existing vegetative component, mimicking recruitment of large and small mast producers, and reintroducing understory species; (2) Exotic plants will be removed and the disturbed areas revegetated with native plant species to improve overall habitat diversity and quality; (3) Where feasible, the existing habitat will be improved, particularly the understory plant components by incorporating shade-tolerant, understory grasses, forbs, shrubs and small trees. In addition, portions of the river bank would be stabilized by re-sloping, and re-vegetating with native forbs, grasses, and woody species where feasible. Where naturalistic approaches are not likely feasible, these erosive areas and other expected high-shear stressed areas could be protected with hard armoring techniques.

Discussion, Summary, and Conclusion. Upon further investigation and consideration, it was decided that further study of ecosystem restoration within the Park Reach was not warranted. The greatest potential for restoration in the Park Reach was the restoration of the Catalpa Channel to a more natural condition by removing the concrete portions and restoring a permanent source of water to the channel. However, without a flood damage reduction project providing a permanent source of water (i.e., diversion of San Antonio River), there is no reliable permanent source of water for the Catalpa Channel, nor can the concrete be removed. Other sources of permanent water for Catalpa Channel were explored including pumping water from the river or re-use water from the San Antonio Water System. However, the adverse environmental impacts from the infrastructure required to pump water, and the "unnatural" sources of water, are not compatible with ecosystem restoration. Therefore restoration of the Catalpa Channel was not considered further. Regarding the San Antonio River, the cost of stabilizing localized erosion by re-sloping, and re-vegetating with native forbs, grasses, and woody species will not produce a level of estimated habitat output as compared to the anticipated costs. Limited aquatic acres and high land costs were factors the decision not to pursue restoration along the San Antonio River, and further study is not warranted.

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